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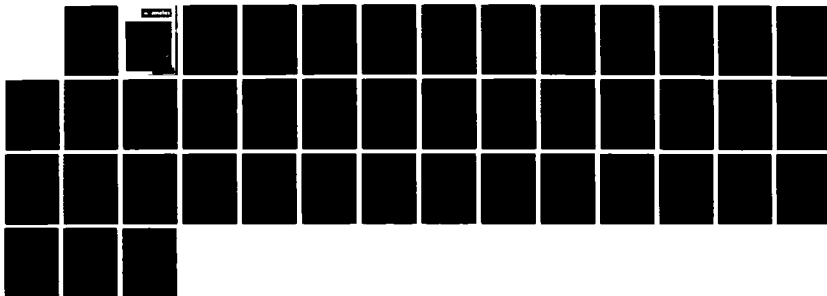
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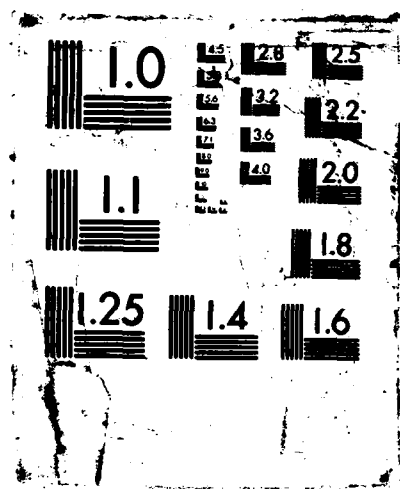
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FINAL REPORT

ANALYSIS OF ATCRBS, MODE SELECT (MODE S) IN COMBAT OPERATIONS

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report investigates the current civilian and military status of the Air Traffic Control Radar Beacon System, Mode Select Program and relates the Mode S capability to future Army operational concepts for Air Traffic Service in a combat situation. The U.S. Army has no stated military or civil requirement for a specific Mode S capability; however, the Army has a need for a system that will provide for aircraft separation, guidance, navigation aids, and airspace deconfliction during combat operations. As the civil and military Mode S capability matures, the military utility of the system may require further analysis.		

ANALYSIS OF ATCRBS,
MODE SELECT
(MODE S)
IN COMBAT OPERATIONS

FINAL REPORT
AMELEX-86-0030

October 1987

J.J. Berner

Submitted to:
Combat ID/EW Division
Fort Monmouth, NJ 07703

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SUMMARY

This study was prepared for the Combat Identification/Electronic Warfare Division, Ft. Monmouth, New Jersey, under the direction of the Army Combat Identification Systems Program Office. Its purpose is to review the impact the implementation of the Air Traffic Control Radar Beacon System (ATCRBS) Mode S will have on Army combat operations.

As part of the National Airspace Plan, the Federal Aviation Administration will update all major components of the existing air traffic control system. One of the new major system components of the ATC system is the Mode S Beacon Interrogator System, a combined secondary surveillance radar and ground-air-ground data link system which will be capable of providing the aircraft surveillance and communications necessary to support air traffic control automation in the dense traffic environment expected in the future. This program is funded, has the support of Congress, and is progressing on schedule.

Since the ground based interrogator is a question and answer system, its interface with aircraft in flight is accomplished through airborne transponders. A recent Federal Aviation Administration rule will require that all transponders installed after January 1, 1992, meet the requirements of the technical standard order (TSO) for airborne Mode S transponder equipment. At present this rule only applies to U.S. civil registered aircraft; however, it is logical to assume that avionics hardware companies will soon cease producing anything but Mode S transponders.

The Department of Defense has no stated requirement for a combat Mode S capability; however, the next generation military question and answer identification friend or foe (IFF) system (the Mark XV IFF

System) will be compatible with and meet the proposed FAA and international civil aviation organization standards, including Mode S air traffic control capabilities.

Army participation in the MK XV CORE program will provide for an airborne transponder capability. At this time there is sufficient evidence available which indicates the Army, on its own, will not support a 100% combat aircraft MK XV transponder requirement. In addition, if a combat capability is to be achieved through Mode S, Army air defense radars must also be provided with a Mode S Beacon Interrogator capability in order to selectively identify aircraft and to utilize the data link capability. A Mode S radar interrogator for Army application is not part of the current MK XV development program.

The U.S. Army has no stated military or civil requirement for a specific Mode S capability; however, the Army has a need for a system that will provide for aircraft separation, guidance, navigation aids, and airspace deconfliction during combat operations. This need is presently stated in the draft Air Traffic Services Operational Concept Statement approved by TRADOC. It describes how Army Air Traffic Services will support combat operations on the air/land battlefield. Air Traffic Service has a peacetime mission of supporting Army aviation training and exercises through fixed base and mobile sites, and these units must be able to interface with host nation airspace requests and sister services during joint and combined operations.

There are many unknowns as to how far the civil and military Mode S capability will progress. As the civil and military Mode S capability matures, the military utility of the system may require further analysis.

I. APPROACH

A. This study was organized into two tasks. The first task was a data collection effort from the appropriate activities of other services and government agencies concerned with combat operations, air defense, air battle management and air traffic control. The most current information was collected from the organizations for the purpose of familiarization with their planning on the subject and, if appropriate, to incorporate data into the report. Agencies which provided data for this report were:

U.S. Army

Headquarters, Department of the Army, Washington, D.C.

ODCSOPS//DAMO - FDV
ODCSOPS//DAMO - FDE
ODCSRDA//DAMA - WSA
ODCSRDA//DAMA - CSC

Headquarters, U.S. Army Europe, Heidelberg, Germany

Headquarters, TRADOC, Ft. Monroe, VA

U.S. Army Aeronautical Services Office, Alexandria, VA

U.S. Army Aviation Center, Ft. Rucker, AL

Counter Air Development Division //ATZQ-CDD
Air Traffic Services Division //ATZQ-CDA
Avionics, Visionics, EW Branch //ATZQ-CDM
Army Air Traffic Control Activity//ATZQ-ATC

U.S. Army Missile Command, Huntsville, AL

PM, Forward Area Air Defense Systems (FAADS)

U.S. Army Laboratory Command, Ft. Meade, MD

PM, Army Combat Identification Systems (ACIS)

U.S. Navy

Deputy Chief of Naval Operations, Air Warfare,
Washington, D.C.

Airspace, Airfields and ATC Br	//NOP-554
FAA Liaison Officer	//NOP-554L
CIS Program Manager	//APC-209
CIS Program Sponsor	//OPNAV-352R

U.S. Air Force

Deputy Chief of Staff Plans & Operation
Washington, D.C.

Airspace and Air Traffic Svc. Div.//XOORF

Tri-Service Organization

Combat Identification Systems Program Office, Dayton, OH

U.S. Army, PM IFF
U.S. Navy, PM IFF

Federal Aviation Administration, Washington, D.C.

Program Manager - Mode S

B. The second task was to assemble, review, analyze and evaluate the data that was collected. A review of the following areas was conducted.

1. The present plans of the Federal Aviation Administration to implement Mode S into the National Airspace System and what impact, if any, the decision will have on Army aircraft.
2. The Army peacetime and wartime requirement for Mode S equipment.
3. U.S. Air Force plans to implement Mode S.
4. U.S. Navy plans to implement Mode S.
5. ICAO actions/intent relative to international airspace.

II. INTRODUCTION

The Mode Select (Mode S) Beacon System is not a new concept. It has its origins in the Discrete Address Beacon System (DABS) concept which was being explored in the early 1970's. System specifications were developed by Lincoln Laboratory between 1972 and 1976. Engineering models were developed and tested at the Federal Aviation Administration's Technical Center at Atlantic City, NJ, between 1976 and 1982. Production specifications were developed and reviewed by industry in 1982.

To properly evaluate the potential of Mode S for future Army combat operations, the most current data providing the functional description of the Mode S Beacon System was reviewed. The following systems data was extracted from the Lincoln Laboratory report, "Mode S Beacon System: Functional Description," Project Report ATC-42 (Rev. D) dated 29 August 1986. All analysis and evaluation of the Mode S system for Army use is based on technical data provided in this document.

"The Mode S Beacon System is a combined secondary surveillance radar (beacon) and ground-air-ground data link system capable of providing the aircraft surveillance and communications necessary to support air traffic control (ATC) automation in the dense traffic environments expected in the future. It is capable of common-channel interoperation with the current Air Traffic Control Radar Beacon System (ATCRBS), and thus may be implemented at low user cost over an extended ATCRBS-to-Mode S transition period. In supporting ATC automation, Mode S will provide the accurate surveillance needed to support automated decision making, and the reliable communications

needed to support data link services. In order to meet these requirements at enroute facilities, Mode S sensors may operate with back-to-back beacon antennas to provide twice the beacon data rate available from a standard antenna. When operating in conjunction with a terminal or enroute digitizer-equipped, ATC surveillance radar, a Mode S sensor will use the radar returns either to reinforce beacon tracks, or in cases of absence or failure of a transponder, to provide radar target reports.

A central Mode S design requirement was assurance that the system could be implemented in an evolutionary manner. By the time deployment of Mode S begins, approximately 1988, there will be on the order of 200,000 aircraft equipped with ATCRBS transponders, and approximately 500 ground-based interrogators. Mode S is designed to operate in this environment, and in a way that would permit the gradual transition to an all-Mode S operation.

The capability for such a transition has been achieved by providing a high degree of compatibility between Mode S and ATCRBS. Mode S uses the same interrogation and reply frequencies as ATCRBS, and the signal formats have been chosen to permit substantial commonality in hardware. This degree of compatibility permits an economic and smooth transition, in which (a) Mode S interrogators will provide surveillance of ATCRBS-equipped aircraft, and (b) Mode S transponders will reply to ATCRBS interrogators.

Thus Mode S equipment, both on the ground and in aircraft, can be introduced gradually and continue to interoperate with existing systems during an extended transition phase.

THE MODE S CONCEPT

The fundamental difference between Mode S and ATCRBS is the manner of addressing aircraft, or selecting which aircraft will respond to an interrogation. In ATCRBS, the selection is spatial, i.e., aircraft within the mainbeam of the interrogator respond. As the beam sweeps around, all angles are interrogated, and all aircraft within line-of-sight of the antenna respond. In Mode S, each aircraft is assigned a unique address code. Selection of which aircraft is to respond to an interrogation is accomplished by including the aircraft's address code in the interrogation. Each such interrogation is thus directed to a particular aircraft. Narrow-beam antennas will continue to be used, but primarily for minimizing interference between sensors and as an aid in the determination of aircraft azimuth.

Two major advantages accrue from the use of discrete address for surveillance. First, an interrogator is now able to limit its interrogation to only those targets for which it has surveillance responsibility, rather than to continuously interrogate all targets within line-of-sight. This prevents surveillance system saturation caused by all transponders responding to all interrogators within line-of-sight. Secondly, appropriate timing of interrogations ensures that the responses from aircraft do not overlap, eliminating the mutual interference which results from the overlapping of replies from closely spaced aircraft (so-called synchronous garble).

In addition to the improved surveillance capability, the use of the discrete address in interrogations and replies permits the inclusion of messages to or from a particular aircraft, thereby providing the basis for a ground-air and air-ground digital data link.

MODE S ELEMENTS

The Mode S system is comprised of the sensors, transponders, and the signals-in-space which form the link between them. Mode S provides surveillance and ground-air-ground communication service to air traffic control facilities including enroute (ARTCC) and terminal (TRACON and TRACAB).

The Mode S link employs signal formats used for ATCRBS, and adds to these the signal waveforms and message formats necessary to acquire Mode S-equipped aircraft, and for discretely addressed surveillance and data link interrogations and replies. The principal characteristics of the Mode S signals are as follows:

Interrogation -

Frequency: 1030 MHz
Modulation: Differential Phase-Shift Keying (DPSK)
Data Rate: 4 Mbps

Reply -

Frequency: 1090 MHz
Modulation: Pulse Position (PPM)
Data Rate: 1 Mbps

Interrogation and Reply -

Data block: 56-bit or 112-bit
Parity code: 24-bit (included in data block)

The Mode S sensor provides surveillance of ATCRBS- and Mode S-equipped aircraft, and operates as a store and forward communication relay for data link communication between aircraft and ATC facilities. In addition, the sensor accepts digitized radar target reports from a collocated radar and combines these with the beacon reports into a composite surveillance output stream. When beacon and radar reports occur on the same target, the radar report is

suppressed and the beacon report tagged as radar-reinforced.

Radar-only output reports are provided on targets that are not beacon-equipped.

To discretely interrogate Mode S equipped aircraft, the sensor maintains a file of the identity and approximate position of all such aircraft within its defined area of coverage.

Each sensor's operation is controlled by a prestored map defining its coverage volume, which may be different in normal operation and in the event of various system failures, e.g., the failure of an adjacent sensor.

In a netted configuration, each sensor may communicate with adjacent sensors via a common ATC facility to hand off targets as they pass from the region of one sensor's coverage to that of an adjacent sensor. In addition, in regions of overlapping coverage, this intersensor communication may be used to assist in the reacquisition of a lost target.

In general, each sensor can provide surveillance and communication services to several ATC facilities, i.e., all those whose areas of control responsibility overlap the coverage area of the sensor. The interface between the sensor and each control facility comprises a one-way circuit for the transmission of surveillance data, both radar and beacon, and a two-way circuit for the interchange of data link messages. The latter is also used to transmit various status and control messages between the sensor and the ATC facility.

The Mode S transponder includes all of the functions of an ATCRBS transponder, and adds to these the ability to decode Mode S interrogations and to format and transmit the appropriate replies.

For data link, the transponder functions primarily as a modem. On receipt of a ground-to-air transmission, it verifies the correctness of the received message using the error-detecting code. Once verified, the transponder transfers the message contents to one or more external devices. For air-to-ground messages, the transponder accepts the message contents from an external input device, and formats and encodes the data for transmission as part of the reply to a subsequent interrogation.

MODE S SURVEILLANCE

The principal features of Mode S surveillance are as follows:

- Unique address
- All-call acquisition
- All-call lockout
- Range-ordered roll-call interrogation
- Adaptive reinterrogation
- Monopulse direction-finding
- Positive handoff
- Multisensor coverage

Each Mode S-equipped aircraft has a permanently assigned unique 24-bit address. This 24-bit address will be included in all discretely addressed interrogations to that aircraft, and in all Mode S replies from that aircraft.

The Mode S sensor range-orders interrogations to Mode S-equipped aircraft in such a way that the replies do not overlap. The use of monopulse direction finding on the reply permits the sensor to provide surveillance of Mode S-equipped aircraft, generally within a single interrogation/reply cycle per rotation (scan) of the interrogator antenna. If a reply to the interrogation is not received, or is received but not successfully decoded, the interrogator has the capability of reinterrogating (several times if necessary) the aircraft during the time the aircraft is in the antenna beam.

In order to be discretely interrogated, an aircraft must be on the sensor's roll-call file; i.e., the sensor must know its address and approximate position. To acquire targets not yet on any sensor's roll-call file, each sensor transmits all-call interrogations. A Mode S-equipped aircraft will respond to such an interrogation with its unique address and be added to the sensor's roll-call file.

Once on the sensor's roll-call file, the Mode S-equipped aircraft may be locked out from replying to subsequent Mode S all-call interrogations. This lockout condition is controlled by the Mode S sensor and is transmitted to the Mode S transponder as part of the Mode S discrete interrogation. The use of Mode S lock-out eliminates unnecessary all-call replies and therefore minimizes interference (particularly all-call synchronous garble) on the air-to-ground channel.

While Mode S lockout can minimize synchronous garble on acquisition, it cannot eliminate it completely nor is it effective in the case where a Mode S sensor resumes operation after a period of inactivity and must therefore acquire many Mode S aircraft simultaneously. These latter cases are handled by a feature called "the stochastic acquisition mode." In this mode, the Mode S sensor interrogates garbling aircraft with a special all-call interrogation that instructs them to reply with a specified less-than-unity replay probability. The resulting reduced reply rate means that some all-call replies will be received ungarbled and these aircraft will thus be acquired. Once an aircraft is acquired, it is locked out and hence no longer interferes with the all-call replies from the remaining unacquired aircraft. The process is repeated until all aircraft are acquired.

The use of Mode S lockout to minimize interference on all-call replies means that provision must be made to hand off the Mode S address to an adjacent site in areas of multisensor coverage. In a non-netted configuration, Mode S aircraft are handed off to an adjacent sensor using one of the following techniques.

Site Address Lockout. The Mode S transponder can be selectively and independently locked out to all-call interrogations originating from up to 15 different sensor sites. Adjacent sites using different site address numbers are completely unaffected by the other sites' lockout activity and hence can perform acquisition and lockout in a completely autonomous manner.

Cooperative Unlocking. This technique requires that each site selectively unlock aircraft at surveillance boundaries in order to allow them to be acquired by the adjacent sensor's normal all-call interrogations.

Lockout Override. A special all-call interrogation can be used that instructs the Mode S transponder to ignore any previous lockout instructions. The resulting all-call garble is handled by the stochastic acquisition mode. While offering reduced performance compared to the other alternatives, the approach provides a means for sensors with overlapping coverage to operate with no site-to-site coordination. Hence it may be useful for operation across national boundaries.

Provision has also been made for sensor-to-sensor transmission of the aircraft's address and position where Mode S sensors with overlapping coverage can communicate via a common ATC facility.

If for any reason an aircraft ceases to receive discretely addressed interrogations for a period of approximately 18 seconds (corresponding to a few interrogator scans), any existing lockout will lapse so that the aircraft may be reacquired by normal Mode S acquisition.

In regions of airspace visible to more than one Mode S sensor, each Mode S target will generally be simultaneously on the roll-call of at least two sensors to provide continuity of surveillance and data link service in the event of a link or sensor failure."

III. INVESTIGATION

BACKGROUND

The Federal Aviation Administration has developed and will procure a new international standard air traffic control component that will interplay with military IFF systems, Designated Mode - Select (S). This new system provides a number of operational features in addition to those currently available in the current Air Traffic Control Radar Beacon System (ATCRBS). These new features are considered by the International Civil Aviation Organization (ICAO) and the FAA to be necessary for the proper and safe operation of commercial aircraft. In the United States, Mode S will initially affect all traffic at altitudes over 12,500 feet. It retains all of the current ATCRBS modes but adds an S mode which has a capability of addressing individual aircraft through a selective procedure and is also capable of an automatic up/down link of data transmission with these aircraft. Military IFF systems all over the world will be required to interplay with this new ICAO system in the modes for ATC. The new functions cannot be added reasonably to existing (FAA) ATCRBS or military IFF systems except through replacement of the hardware. Installations and operation of the new Mode S systems by the ICAO and the FAA in their ground stations and aircraft will have some effect (from minor to extremely major) on the Army's IFF systems and combat operations, depending upon the amount of interplay that is desired and/or required.

By existing laws, the FAA is responsible for the control of all flights over the Continental United States (CONUS). This responsibility includes not only all of the United States and international commercial aircraft, but also includes the military

aircraft of the United States and the NATO countries. The respective civil aviation organizations of each individual country perform the same function as the FAA in the national airspace of those countries, as does the ICAO for international airspace. All aircraft (including the Warsaw Pact) now use the current FAA Air Traffic Control System (ATCRBS). If any of these users desire the new advantages of the Mode S, they will have to replace their existing IFF or ATCRBS hardware with the FAA Mode S (or military equivalent) hardware. The Mode S, at this time, is not a mandatory requirement, and the users who elect to stay with their existing IFF or ATCRBS systems will continue to receive the same FAA air traffic control they now have over CONUS. However, it appears that sometime in the future, after suitable DoD/FAA negotiations, some portion of the Mode S capability will be required of all aircraft.

Mode S adds two features to the current ATCRBS: (1) It provides the capability to address (challenge) a selected aircraft, or a selected number of aircraft, equipped with Mode S transponders to the exclusion of all aircraft not selected; and (2) It provides an automatic means via the up/down data link of transmission for supplying weather reports, operational messages, traffic details, etc., between the Mode S transponders and Mode S ground stations. Mode S systems have been designed to be evolutionary by inter-operating simultaneously with all ATCRBS, IFF, and Mode S transponders. Therefore, all aircraft can be under the control and surveillance of any civil or military unit and will receive services during the interim period between initial installation to final completion of the worldwide system.

Mark XII military transponders and its predecessor, Mark X (SIF) transponders, will interoperate satisfactorily with any mix of ATCRBS/ Mode S ground stations via any combination of the ATCRBS signals Modes 3/A and C. Military transponders will also respond simultaneously to military interrogating systems in Modes 1, 2 and 4, as well as Modes 3/A and C. As long as the civil stations continue to use Modes 3/A and C, military aircraft can be kept under civil control and surveillance without requiring the Mode S discrete address and up/down link or data signals. Mark XII military transponders will not reduce or degrade the benefits of the Mode S systems operating against Mode S transponders installed in commercial aircraft. To obtain all of the Mode S benefits in military aircraft, a military version of the FAA design must be developed having the capabilities of all of the military modes 1, 2, 3/A, C and 4 plus the discrete address and up/down link functions.

FEDERAL AVIATION ADMINISTRATION RULE MAKING

The final rule concerning Air Traffic Control Radar Beacon Systems and Mode S Transponder Requirements in the National Airspace System was published in the Federal Register on February 3, 1987. It is important to understand the direction and intent of the FAA concerning future Mode S equipment requirements since the DoD requirement for compliance is stated in the JCS Multi-Command Required Operational Capability (MROC 20-83). Army considerations of Mode S will be discussed in following paragraphs.

The following are extracts of the Final Rule which are of importance to DoD. The entire rule is found on pages 3380 through 3390 in the Federal Register dated 3 February 1987.

Agency: Federal Aviation Administration (FAA), DOT.

Action: Final rule.

Summary: This action establishes requirements pertaining to the use, installation, inspection, and testing of Air Traffic Control Radar Beacon System (ATCRBS) and Mode S transponders in U.S.-registered civil aircraft. The rule adopted continues to require a transponder for operation in each terminal control area (TCA) and in the airspace of the 48 contiguous states and the District of Columbia above 12,500 feet above ground level (AGL). Automatic pressure altitude reporting equipment, which is currently required in all of the above airspace except Group II TCA's, will be required in Group II TCA's effective December 1, 1987. The rule provides for a phased transition from ATCRBS to Mode S transponders in the National Airspace System (NAS) by limiting the manufacture and installation of ATCRBS transponders. After January 1, 1992, all newly installed transponders in U.S.-registered civil aircraft are required to meet the requirements of the technical standard order (TSO) for airborne Mode S transponder equipment. The rule also permits ATCRBS transponders already installed on that date to be used indefinitely. Projected increases in air traffic will require improved aircraft location and identification information, which will be provided by the Mode S and automatic pressure altitude reporting equipment. These requirements are an essential component of the

NAS Plan. Mode S is also a necessary technical prerequisite to obtain data link services which allow digital exchange of information between aircraft and the ground. The FAA will provide these services beginning on/about 1990. This action also sets forth test and inspection requirements for the Mode S transponder and a new output power test requirement for the ATCRBS transponder.

Supplementary Information: The three kinds of aircraft equipment addressed by this rulemaking are as follows:

Air Traffic Control Radar Beacon System (ATCRBS).

A radar system in which the aircraft to be detected is equipped with a radio receiver/transmitter called a transponder. Radar pulses transmitted from the ground are received by the transponder and used to trigger a distinctive transmission from the transponder. The controller's radar receives this transmission and displays a distinct and amplified return on the radar scope.

Mode S Transponder. The Mode S Transponder is an advanced version of the existing ATCRBS transponder. The Mode S transponder is completely interoperative and compatible with the current ATCRBS system.

Mode S utilizes a discrete set of radio pulses (code) for each individual aircraft, and is not limited to the maximum 4,096 possible codes of the ATCRBS transponder. Mode S also adds the capability to

provide a data link between the aircraft and the ground.

Mode C (Automatic Altitude Reporting Equipment).

Some transponders are equipped with a Mode C capability. Mode C is that function of a transponder which responds to specific ground interrogations by transmitting the aircraft's current altitude in 100 foot increments. This information is received by ground equipment and displayed on the controller's scope in the data block for the transmitting aircraft. Mode C may be used with both ATCRBS and Mode S transponders.

Summary of FAA Actions: Consistent with FAA's plan to modernize the NAS, and the planned role of the Mode S surveillance system in the NAS, the FAA is taking or has taken the following actions:

1. Issue a TSO for airborne Mode S Transponder.

Concurrently, TSO authorization to manufacture ATCRBS transponders will continue in effect. The intent of continuing the ATCRBS TSO is to allow continued manufacture of ATCRBS transponders for foreign sale and for installation in aircraft destined for foreign countries and to accommodate the DoD.

Issuance of the TSO's is not accomplished through rulemaking and, therefore, the Mode S TSO is not a regulatory portion of this rulemaking package.

However, consistent with FAA practice, the proposed

TSO for Mode S was made available for public comment. All issues generated by public comment were resolved and TSO-C112 was issued February 5, 1986.

2. Amend the Federal Air Regulations (FAR). The following changes to the FAR are adopted by this amendment:

FAR Part 43, Appendix F. ATC transponder test and inspection requirements apply to both ATCRBS and Mode S transponders. Test areas include radio reply frequencies, suppression, receiver sensitivity, radio frequency, and output power. Those tests applicable only to Mode S transponders include Mode S diversity transmission channel isolation, Mode S address, Mode S formats, Mode S all-call interrogations, ATCRBS-only all-call interrogations, and squitter. The reference to Section 91.177 is corrected to refer to Section 91.172. The existing requirement for recordkeeping will be retained.

FAR Part 91, Section 91.24(a). For operations not conducted under Parts 121, 127, or 135, ATC transponder equipment installed (or in fleet operations, equipment introduced into the fleet inventory) within specific time periods must meet the performance and environmental requirements of the TSO's specified in the rule. The requirement to meet the Mode S TSO after January 1, 1992, does not apply to -----

- a) A transponder which met the requirements of the rule when originally installed, and which is removed from an aircraft for maintenance and then reinstalled on the aircraft from which it was removed.
- b) A transponder which meets the requirements of TSO C74b or TSO C74c and is temporarily installed on an aircraft when the permanent transponder is removed for maintenance.
- c) A transponder which met the requirements of the rule when originally installed in a fleet aircraft, which is removed from the aircraft for maintenance/repair, and which is then installed on either the aircraft from which it was removed or on another aircraft in the same fleet.

Section 91.24(b). All aircraft operated in the airspace areas defined below are required to have either a combination ATCRBS or Mode S transponder and automatic pressure altitude reporting equipment. The new requirement applies as follows:

- 1. in Group I TCA's;
- 2. in Group II TCA's; and
- 3. in all controlled airspace of the 48 contiguous States and the District of Columbia, above 12,500 feet MSL, excluding the airspace at and below 2,500 feet AGL.

Automatic pressure altitude reporting (Mode C) equipment is required in Group II TCA's.

Exceptions to the rule are as follows:

1. Operations of helicopters in TCA's at or below 1,000 feet AGL under a letter of agreement.
2. Operations of gliders above 12,500 feet MSL but below the floor of positive control area.

No Group III TCA's exist or are planned.

An editorial change has been made to substitute the word "operating" for the word "operable" in Section 91.24(b). Substitution of the word "operating" for the word "operable" is made to reflect the requirement that transponders must be turned on. Section 91.90(b)(2)(iii). Aircraft operating in Group II TCA's are required to be equipped with automatic pressure altitude reporting equipment effective December 1, 1987.

JCS MULTI-COMMAND REQUIRED OPERATIONAL CAPABILITY (MROC)

The MROC 20-83 states the DoD requirement for a next generation Question and Answer Identification Friend or Foe (IFF) System and addresses military Mode S implementation by stating "...The objective is to minimize retrofit cost; to this end, the transponder will include the required air traffic control modes and capabilities in the same equipment so as to preclude the need for a separate transponder...In addition, it shall be compatible and interoperable with existing and proposed FAA and international civil aviation organization standards, including Modes "C" and "S" air traffic

control capabilities...This requirement will include the capability that, with additional equipment, full use of Mode "S" data link services could be made available."

TRI-SERVICE MK XV PROGRAM

The DoD implementation of the MROC has resulted in a Tri-Service Program Office, under USAF lead, located at Wright-Patterson AFB. The Combat Identification Systems Program Office (CISPO) is developing hardware known as the MK XV Identification Friend or Foe (IFF) System.

The MK XV Joint Program Office is developing a core program funded by the President's FY88 Budget. It includes a Total Obligation Authority (TOA) transfer from the Army and Navy to the Air Force for the full-scale development core program from FY88 to FY92. The core configuration items and core test platforms include:

<u>Core Configuration Item</u>	<u>Core Integration Platforms</u>
Standard Transponder (Remote) (Replaces APX-100) Remote	F-15A-E F/A-18A
Standard Transponder (Panel Mount) (Replaces APX-100) Panel Mount	EH-60
Airborne Interrogator (Replaces APX-76)	F-15A-E
Ground Interrogator (Replaces TPX-46(VI))	THAWK
Ship Interrogator (Replaces UPX-23/27)	AEGIS/Spruance

Engineering for integration efforts of MK XV core configuration items on other platforms are considered service unique. Therefore, requirements and funding are the responsibility of the individual services.

The USAF Program Management Directive for the MK XV program directs the Program Office to plan and provide design interface for incorporation of Mode S into the MK XV system at Level I and directs a study to be conducted as to the cost impact of the incorporation of additional levels. To date the MK XV program includes Mode S Level 1 capability in the transponder, but the specifics of operation are not defined. The MK XV interrogator does not include a Mode S capability.

The DoD has informed the FAA that the MK XV will include the Mode S function, and that the DoD implementation of Mode S will coincide with the implementation of the MK XV. However, it should be noted that the present MK XV Program plans only include Level 1 (56 bit message length) in the MK XV transponder which precludes any data link capability in the future should the requirement or desire develop.

U.S. NAVY IFF PROGRAM

The U.S. Navy relies heavily on the current MK XII question and answer IFF system as both an aircraft identification system and a combat command and control system. Though the Navy has no stated wartime requirement for a Mode S capability, the next generation question and answer system (MK XV with a Mode S capability) will be utilized to its fullest capability in both peacetime and wartime operations to emulate the current MK XII system.

Though no formal studies have been conducted to date by the Navy concerning wartime use of Mode S, the extensive battle management functional use of the current IFF system would be enhanced with the additional data link capability provided with the Mode S equipment.

The U.S. Navy air traffic control community stated during the FY 87 Naval ATC conference that all MK XV transponders will include a Mode S reply capability which is specified at level I. It was also stated that a transponder capability of Mode S level II is the minimum capability required by the ATC community, while full level III capability is desired for Navy aircraft to operate in the National Airspace and be interoperable with the FAA air traffic control system. For shore station ATC a full Mode S interrogation and data link capability, level III, will be required due to interoperability requirements with the FAA, particularly as relates to special use airspace. In addition, the Navy plans to equip all Navy training aircraft with commercial Mode S transponders. It is apparent at this time that the Navy is giving serious consideration to the future potential of Mode S when implemented through the MK XV program.

The U.S. Navy, as the most active user of the current question and answer IFF system, fully supports the new MK XV question and answer system. When the Multi-Command Required Operational Capability (MROC) requirements are met, the operational use of the new system will emulate the current MK XII system. Detailed standard operational procedures will be developed and promulgated through the Allied Communication Publication 160 (APC-160). Detailed specialized procedures will be developed for wartime by tactical commanders. However, full MK XV advantages will not be realized until all interrogators and transponders are MK XV capable.

U.S. ARMY CONSIDERATIONS

A. ARMY AVIATION REQUIREMENTS:

The leadership in the Army responsible for Army Aviation proponentcy has recently restated the Army Aviation position/requirement for the MK XV IFF system as it relates to airborne transponders for aircraft. The Army Aviation Center is on record as supporting the requirement for a positive passive hostile identification system in order to maximize the effectiveness of air defense weapons systems and reduce fratricide. The MK XV as an active question and answer system does not totally meet this aviation requirement. The Aviation Center uses as rationale that the MK XV provides only marginal improvements over the fielded MK XII IFF systems when used in combat at nap of the earth altitudes. They further rationalize that the minor improvement provided by MK XV capabilities when compared with the projected cost of the avionics to be installed in Army aircraft does not justify the expenditure of aviation procurement dollars for the MK XV system. Army Aviation supports the development of an Army combat identification system which uses non-cooperative target recognition techniques. The Aviation Center does not support the installation of the MK XV IFF system on current attack helicopters as previously directed by Headquarters, Department of the Army, and has suggested that the previously stated requirement for special electronic mission aircraft (SEMA) should also be reconsidered in light of the recently completed combat identification system (CIS) study conducted by the TRADOC community.

role is directly influenced by Army Airspace Command and Control (A²C²) efforts to synchronize all users of battlefield airspace. These services provide for effective utilization of friendly airspace while reducing enemy capabilities to locate and attack friendly aircraft and support facilities.

ATS has a peacetime mission of supporting Army aviation training and exercises through fixed base and mobile sites. ATS units must be able to interface with host nation airspace requests and sister services during joint or combined operations.

The threat to ATS varies according to the intensity of conflict and location. Mid to high-intensity combat is characterized by broad frontages, deep targets, and enemy penetrations of varying depths. Nuclear and chemical fires may be employed. Sophisticated EW equipment utilizing radio-electronic combat (REC) will be employed. ATS systems positioned near critical command and control nodes and other lucrative rear area targets may suffer collateral damage during aerial, rocket, artillery and heliborne assaults. Opposing forces can employ precision-guided weapons and anti-radiation missiles against active ATS emitters. Low-intensity warfare is characterized by broad frontages, semi-autonomous operations conducted at varying depths, and rear area security problems. Prepared airfields, permanent bases, and fixed support facilities can be expected to be primary targets of opposing irregular and special operating forces.

The ATS concept focuses on the Army's participation in the synchronization of airspace users and the joint interface and coordination required to effectively conduct combat, combat support, and combat service support operations on the air/land battlefield.

B. AIR TRAFFIC SERVICE CONCEPTS:

The recent shift of Air Traffic Control proponency from the U.S. Army Information Systems Command to the U.S. Army Aviation Center has lead to the development of a new, forward-looking operational concept for Army air traffic services which will require and rely on command and control capabilities and aircraft identification systems. The concept statement describes how the Army Air Traffic Service (ATS) will support combat operations on the air/land battlefield. It provides an overview of ATS functions within the deep, close, and rear battle areas across the spectrum of conflict intensity. It is intended to orient the Army in the right direction during development of ATS operational concepts and future doctrine, training, equipment and force structure.

The U.S. Army air/land battle umbrella concept emphasizes that initiative, depth, synchronization, and agility will be key factors in the Army's success on the battlefield. These tenets must be inherent in all ATS operations and functions. ATS will support the combined arms team by facilitating the execution of these doctrinal principles. Deconfliction and synchronization of all airspace within the air maneuver envelope is a critical element of the overall campaign plan and must be addressed by commanders at all levels.

In order to successfully meet the challenge of supporting air/land battle objectives, ATS requires an increased capability to support the maneuver commander at crucial times and locations. ATS units will be required to effectively operate in deep, close, and rear operations, throughout the spectrum of conflict intensity, and in any number of geographical locations. The Air Traffic Service's wartime

The operational concept of air traffic service includes the following:

Mission. The primary mission of Army ATS is to facilitate the synchronization and integration of all U.S. military and allied aircraft in both peacetime and conflict, anywhere in the world. In order to accomplish this, essential services are provided during each type of conflict and for all areas of the air/land battlefield. These services include aircraft separation guidance, navigation aids, information updates, and airspace deconfliction for both terminal operations and enroute flight.

Deep Operations. Deep operations are largely characterized by constrained airspace and transit corridors forced open by the suppression of enemy air defenses. During cross-FLOT and deep operations, ATS elements, equipped with portable systems, working in conjunction with joint and combined control teams, pathfinders or long-range surveillance units deploy to assist aviation units with navigation, drop zone, and landing zone support to the extent necessary to accomplish the mission. Additionally, ATS navigational systems may be emplaced and remoted by other organizations to facilitate the same. ATS teams assist in synchronization of the commander's maneuver plan, providing landing and takeoff deconfliction for aircraft for deep operations. Additionally, ATS units with enhanced communications rapidly pass real-time critical A²C² information between Army and joint airspace users. ATS complements special operations by providing specific navigational assistance during long-range penetration missions.

Close Operations. Army aviation forces maneuver across the battlefield using maps and onboard navigation systems while carrying

out tactical operations within the fluid, combat-intensive close-in battle area. In adverse weather some aircraft capabilities are reduced; however, they still operate visually to locate and fight the enemy. ATS elements assist aviation maneuver forces and facilitate A²C² implementation by providing terminal landing zone (LZ) and pick up zone (PZ) and enroute flight services during the close battle. Mobile ATS teams operate in the forward areas to aid aircraft flying between supply, medical, and assembly areas and by controlling small tactical terminal areas. ATS elements can provide a limited IMC recovery capability during critical situations and for joint logistics missions when required by weather conditions and operational factors. ATS functions within the A²C² network by providing enroute battlefield and flight information updates to aircraft in the close battle area. Real-time communication links allow the Battlefield Airspace Information Center (BAIC) to transmit flight and airspace advisory information based on changing battlefield situations to Army units. While ATS support to the close-in flight is deliberately austere in nature, as the tempo slackens, ATS elements, augmented with additional ATS capabilities, can increase services to aircraft.

Rear Operations. Rear areas ATS will be characterized by airfield operations, aircraft transitioning from altitude to very low level as they fly forward, and both fixed and rotary-wing traffic. Additionally, joint, combined service, Army SEMA, UAVs, and drones operate at low/medium altitudes and standoff distances dictated by mission requirements. In the division and corps area, aircraft performing command and control, combat support, and combat service support will operate day and night, in adverse weather, and will vary

between low-level to terrain flight depending on the location and enemy situation. ATS elements supporting the rear battle provide enroute aircraft separation, deconfliction, navigation assistance and terminal services. These services include landing and takeoff deconflictions, dissemination of flight and weather information, passive or demand-activated all-weather precision landing sites, and airfields depending on mission, enemy, terrain, troops and time available (METT-T) and the commander's intent. ATS elements within the division and corps will also be a real-time executive of the A²C² plan. ATS assembles air situation input and communicates this to higher and lower ATS elements, A²C² cells, and joint air traffic services organizations. In the theater, ATS units will provide terminal services, including dissemination of weather and flight information, for designated Army, joint, and combined services aircraft at all-weather landing sites and airfields. These theater ATS elements interface with the airspace deconfliction and navigational services as dictated by the airspace command authority. ATS elements must be as mobile as the ground elements of supported organizations and will be packaged to meet the needs of the commander.

Low-Intensity Conflict. ATS elements are capable of supporting Army, joint, and multi-national aviation assets during foreign internal defense (FID), terrorism counteraction, peacekeeping, and contingency operations. ATS units are designed to be easily transportable and quickly put into action. During these types of conflict, a reduced air defense threat will allow ATS units to support sustainment bases in divisional/brigade areas, facilitating movement

of troops and supplies. ATS units may be also required to integrate fixed base facilities with Host Nation control systems and provide terminal and enroute deconfliction, weather, and information advisory functions.

Required Capabilities. ATS units are lightweight, air/ground mobile, and modular configured for flexible tailored employment based on battlefield area operations. ATS organizations have the ability to quickly accept additional ATS calls and equipment modules in order to enhance their operational capabilities. They are capable of data/voice communications with appropriate sister service elements, all airspace users, and aircraft in all mission profiles. All ATS mobile and fixed bases are equipped with secure and ECCM capable communications. These are interoperable with joint facilities via a universally compatible sensor system that interfaces with airborne receivers through real-time digital links. ATS sites add a redundant target acquisition and vectoring capability through large screen displays that integrate numerous information-gathering systems. ATS is capable of providing support in most weather and natural light conditions and at the lowest possible operational altitudes, enhancing aircraft survivability and mission accomplishments.

C. ARMY AIRSPACE COMMAND AND CONTROL IN THE COMBAT ZONE:

The U.S. Army has for many years recognized the importance of the airspace control function on the modern battlefield. Within the airspace a high density of friendly weapons systems and aerial vehicles will be required to contribute the maximum amount of combat effectiveness without interfering with each other. Effective airspace command and control will assist in the coordination, integration and

regulation of the use of combat airspace. It should also provide for the identification of all airspace users.

Airspace control involves four basic functional activities..... command and control, air defense, some aspects of fire support coordination, and air traffic control.

Air battle management in combat is complex and requires real time data input, evaluation, and command and control capabilities. At present two basic methods are used to exercise air battle management....positive management which uses real time data from radars; IFF; computers; data links; and communications equipment.....and procedural management which relies on the use of tactics, techniques, procedures, rules of engagement, and weapons control status.

The Army is presently developing the doctrine which will govern how airspace command and control will be carried out in a combat zone. The existence of present systems and equipment or the development of future systems and equipment that provide the capabilities of air traffic service, air traffic control, identification procedures, and methods of positive and procedural control will all play an important role as to the final doctrine that evolves. Host nation civil ATC systems interface and international civil aviation organization interface will also have an impact on combat operations during low intensity or peacetime contingency operations.

THE CIVIL RESERVE AIR FLEET PROGRAM (CRAF)

A cooperative program to utilize civil air transportation resources to meet civil and military needs during national and defense oriented emergencies is formalized through a Memorandum of Understanding (MOU) between the Department of Defense and the

Department of Transportation. Using this document, the Secretary of Defense has developed a cooperative plan entitled the Civil Reserve Air Fleet (CRAF) program with the civil air carrier industry to augment Department of Defense (DoD) organic airlift capability. Under the CRAF program, U.S. civil air carriers normally enter into annual contracts with DoD and voluntarily commit their aircraft to the three CRAF stages mentioned in the MOU. The number and type of aircraft may change annually based on the current fleet of aircraft being operated by each specific air carrier. There could be as many as five hundred (500) aircraft committed to the CRAF program during the highest state of emergency. The actual number and types of aircraft are determined by the DoD. The specific responsibilities of both DoD and DoT are promulgated in the current MOU.

The DoD has delegated to the Secretary of the Air Force, as the Single Manager of Airlift Services for DoD, through his designee, the Commander-in-Chief, Military Airlift Command (MAC), the responsibility to administer the MOU for the Air Force.

Since the intended use of the CRAF aircraft during military emergencies is to augment military cargo assets to transport troops and equipment to and from a war zone, the military must retain the capability to identify and sort these aircraft as friendly when used in hostile areas. The recent ruling by the Federal Aviation Administration concerning newly installed transponders in U.S. registered aircraft after January 1, 1992, will eventually affect the entire fleet of CRAF aircraft. Over time, as the civil fleet equips with Mode S transponders, air defense units using the MK XV interrogator may lose the ID response capability that is available

with existing ATCRBS equipment. This equipment incompatibility could result in a degradation in the sorting of unknown aircraft at a critical time during emergency situations for the military.

IV. FINDINGS

- The Federal Aviation Administration (FAA) is engaged in the modernization of the National Airspace System. Both the user community and the Congress have supported the need for modernization since the enactment of the Airport and Airway Improvement Act of 1982. Advanced automation is key to system improvements. The Mode S surveillance capability provides more accurate positional information for air traffic control functions, and it also provides the medium for a digital data link to be used to exchange information between aircraft and various air traffic control facilities and weather data bases.

- The FAA is aggressively pursuing the implementation of both Mode S ground interrogators and airborne transponders. By 1993, Mode S and data link coverage will be provided down to 12,500 feet MSL and to the surface at some designated airports. Mode S and data link coverage by 1995 will be extended down to 6000 feet MSL.

- The FAA has stated that in the future airspace system, some specific equipment may be required to operate in designated airspace.

- The FAA final rule on Mode S transponder requirements states that after January 1, 1992, all newly installed transponders in U.S. registered civil aircraft are required to meet the technical standard order (TSO) for airborne Mode S transponder equipment.

- The MK XV military IFF system under development provides an air traffic control transponder Mode S capability with limited data link capability.

- The MK XV military IFF system under development does not provide the interrogator with a Mode S capability, thereby limiting any possible combat use of the Mode S capability.

- Over 500 aircraft in the civil fleet are earmarked for military use during wartime to carry troops and equipment to and from hostile areas. These aircraft are part of the Civil Reserve Aircraft Fleet (CRAF) and will eventually be equipped with Mode S transponders. As the civil fleet equips with Mode S transponders, air defense units will lose the response capability that is available with existing ATCRBS equipment. This could result in a degradation in the sorting of unknown aircraft.

- The Army is presently re-evaluating the concept which will provide air traffic services during combat operations. A new operational concept has been approved which states the need for a system that will provide for aircraft separation, guidance, navigation aids, information updates, and airspace deconfliction for both terminal operations and enroute flight.

- The Army has published doctrine and procedures for Army Airspace Command and Control (A^2C^2) in a Combat Zone. Identification and control of combat aircraft is a major concern in order to maximize combat effectiveness of these assets.

- An airborne data link capability tied in with combat air defense units would be a valuable aid to real time A^2C^2 .

- A recent policy statement from the Army Aviation community negates the requirement for MK XV transponders on Army aircraft as the replacement for the existing MK XII system.

V. CONCLUSIONS

- The basic requirement for Mode S is still driven by the civil air traffic control requirements of the FAA and the modernization of the National Airspace System.

- There is no stated military requirement for Mode S; only a requirement that the new MK XV IFF system be compatible and interoperable with existing and proposed FAA and international civil aviation organization standards.

- The present MK XV program (with Mode S) offers little or no increase in combat capability for the Army since air defense interrogators will not have a Mode S capability and the Army aircraft fleet will not be 100% equipped with MK XV transponders.

- If Army aircraft are required in the future to equip with a Mode S capability in order to operate fully in the National Airspace System, that capability will probably be achieved through the purchase and installation of civilian off-the-shelf Mode S transponders.

- As the civil and military Mode S capability matures, the military utility of the system will require further analysis.

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